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In Conjunction With:
Department of Land and Natural Resources
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Largemouth Bass: a Stock Enhancement Program for Wahiawa Reservoir

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Abstract:

Largemouth bass were captured from a local reservoir for the purpose of remote breeding. Bass were released into a much smaller reservoir where conditions were employed to facilitate the collection of eggs. Offspring from the bass were to be reared in a captive environment, then released back into the reservoir in an effort to improve fishing success and satisfaction of local anglers; however, these fish never reproduced. Among possible reasons why bass did not spawn are stress and water chemistry. These theories, as well as supplemental information pertaining to the rearing of this species, are discussed in the following report.

Introduction:

The largemouth bass, *Micropterus salmoides,* is a favorite freshwater game fish of North America. The popularity of this species has led to it becoming the most managed warm water fish in the United States (McInery and Degan 1993). *M. salmoides* belongs to the sunfish family and contains a variety of strains, each with its unique characteristics and growth potentials. In general, largemouth bass are described as being spiny-finned, perch-like fish with laterally compressed bodies and slightly forked tails. Bodies are covered by scales and are blackish-green along the dorsal surface with lighter coloration below. The world's official record largemouth bass was weighed in at 22 pounds 4 ounces and was taken from Montgomery Lake, Georgia, in 1932. This particular fish is thought to have been a *floridanus* subspecies (McClane 1974).

The longevity of a largemouth bass is a product of location and gender. Those fish residing in northern portions of their range have been found to live longer than those in southern regions. However, fish in southern regions experience longer growing seasons due to warmer climate and, therefore, are able to grow to a much larger size. Females of this species typically live longer than males and have a maximum breeding age of 15 years (Largemouth Bass Taxonomy 1996 - URL #1). The minimum breeding age is a topic of controversy, although, most biologists believe that sexual maturity is based on an age and size relationship (Crumpton et al. 1977). Trebitz (1991) reports that the reproductively mature length for this species is approximately 25 cm and is rarely achieved in one growing season.

Largemouth bass typically spawn during the spring. There are a number of environmental factors that contribute to stimulating the internal mechanisms that lead to the reproductive cycle. Among these factors are length of the photoperiod, tide and moon cycles, and weather patterns (Rottmann et al. 1991). Also, of particular importance is water temperature. Using his tail, the male bass will fan out a nest when water temperatures stabilize above 60 °F. Nests are shallow, circular, and approximately twice the body length of the male fish. A sand or gravel substrate is preferred and is usually chosen in a near-shore location 1 to 4 feet deep. Upon completion of the nest, the male bass entices a female to spawn. Females usually average between 2,000 and 7,000 eggs per pound of body weight. Multiple spawning is common and may, or may not, occur between the same pairs. Females will normally release about half of the eggs they carry in any one spawn. The male fertilizes the eggs as they are released by the female. Eggs are adhesive and clump together in the bottom of the nest. Many females may choose the same nest and the number of eggs per nest may vary from a few hundred to several thousand (McClane 1974).

After releasing her eggs the female bass departs, leaving the male to guard the nest. This is a very stressful period for the male bass and often results in death for him and the nest. Typically, in nature, less than 1% of all eggs produced will survive (Trebitz 1991). Often times entire nests are lost due to predation or other changes in environmental conditions. For those eggs that do survive, hatching will normally occur within 10 days and is greatly influenced by warmer temperatures (McClane 1974). Newly hatched larvae are poorly developed and unable to swim. They obtain their nourishment from absorption of the yolk sac which may last up to 7 days. After these tiny fish develop the ability to swim, they are referred to as fry (those fish that have commenced free-swimming and are $\leq$ 16mm). Fry swim in close-knit schools and feed on zooplankton in the shallow waters. The male parent will continue to guard the fry for approximately one month after they leave the nest (Brown 1984).

As the fry continue to develop, they will begin adding insect larvae and smaller fishes to their diet. At 1 to 2 inches in length, the male parent will abandon the fry and the school will disperse. These small fish are now referred to as fingerlings (those fish $\geq$ 16mm and less than one year of age) and will typically measure 2 inches in length when 40 to 65 days old, and 6 to 8 inches at 100 days under favorable conditions (Lock 1988). Fingerlings will continue to grow as they expand their diet to consume a variety of organisms including insects, worms, minnows, fish, crayfish, and frogs. Adult largemouths have even been known to attack blackbirds, small ducklings, and the occasional field mouse that happens to fall into the water (The Fishing Network 1985 - URL #2).

Largemouth bass occur naturally in eastern North America (Wiley 1996). However, due to its widespread popularity, the largemouth bass, or black bass as it is sometimes referred to, has been the subject of massive stocking programs. Today, as a result of these programs, this species may be found in almost every corner of the continental United States and Hawaii (Murray et al. 1981). One such stocking took place in Wahiawa Reservoir, on the island of Oahu, where "Because of the marked scarcity of native game fishes in Hawaii's fresh water areas, the Division of Fish and Game initiated a program of introducing desirable freshwater game fishes" (Carter 1964). Largemouth bass released into Wahiawa Reservoir are of the *northern* subspecies which rarely exceeds 10 pounds. Hawaii's official state record largemouth stands at 8 pounds and was caught in 1977 (Division of Aquatic Resources 1993).

Initial introductions of largemouth bass into Hawaii's waters occurred in 1896 (Division of Aquatic Resources 1993). However, it was not until the early part of the 1950's that this species was introduced into Wahiawa Reservoir (Higashi - personal communication). Since that time, the popularity of the sport of bass fishing has been realized among many of the island's residents. However, as the popularity of the sport has increased, the number of largemouth bass in Wahiawa Reservoir has noticeably decreased (Hawaii Freshwater Fishing Association members - personal communication). Currently, this population is thought to be in serious decline and managerial efforts must now be taken to increase their numbers. In response to this, management officials at the Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR), have allocated funding for the Hawaii Institute of Marine Biology (HIMB) to create a stock enhancement program for the reservoir. The goal of this program is to improve fishing conditions on Wahiawa Reservoir by capturing largemouth bass, harvesting their eggs, and raising their young in a protected environment until such a time that their release back into the reservoir will likely result in elevated survival rates. This project sought to aid in initiating the stock enhancement program while providing myself the opportunity to become more familiar with the *M. salmoides* species and the responsibilities involved in fisheries management.

Materials and Methods:

Two sites on the island of Oahu were selected for the purpose of breeding largemouth bass. One site, Kualoa #3, is a 1.5 surface acre reservoir located off Kamehameha Hwy on the east shore. The other, Nuuanu #3 Reservoir, is approximately 3 surface acres located just off the Old Pali Hwy. Permission to use a third site, the quarry pond located on the University of Hawaii's (UH) lower campus, was later granted by UH grounds-keeper Mr. Farouk Wang.

Spawning trays, constructed by HIMB for a previous project, were placed in the reservoirs to provide an enhanced location for bass to spawn. This action was taken in order to facilitate collection of eggs for remote hatching on Coconut Island. Trays were constructed from plastic coated, 1cm mesh-wire in a 3ft. x 3ft. x 4in. form. Each tray was filled with $1ft^3$ of small blue coral chips which completely covered the bottom of the tray. A 3ft. length of string was attached by one end to the corner of each tray. A small fishing float was tied to the other end of the string to aid in locating submerged trays. Trays were then submerged in various near-shore locations at a water depth of no more than 3ft. Spatial arrangement of trays was determined in accordance with McClane's (1974) observation that nests are typically separated by a distance of no less than 20ft. A total of 7 trays were placed in the Kualoa location and 5 were placed in Nuuanu.

Members of the Association of Freshwater Sport Anglers (AFSA) and Hawaii Freshwater Fishing Association (HFFA) readily agreed to hold special fishing events on Wahiawa Reservoir for the purpose of collecting broodstock for the program. Approximately 15 club members attended the first AFSA/HFFA event, held 2/2/97, which resulted in the collection of 11 largemouth bass (see Appendix I). Club members used common visual indicators such as the presence or absence of a swollen reddish genital papilla, shape of the scaleless area surrounding the urogenital opening, and fullness of the abdomen (presumably due to the existence of eggs) to sex each individual fish. These observations resulted in their determination that 8 of these fish were likely females and 3 were likely males. All 11 fish were then transported by Mr. Glenn Higashi of DAR using a vehicle equipped with tank and aerator. A soluble type tranquilizer was added to the water in the tank to calm the fish during transport. All 11 of these fish were released into Kualoa Reservoir #3. An individual effort, by HFFA member Mr. Lance Marugame, resulted in the release of 3 more largemouth bass into Kualoa Reservoir #3 on 2/9/97. Mr. Marugame determined by these same type of visual observations that all 3 of these fish were likely males.

A second fishing event, held on 3/2/97, was attended by 9 HFFA members and resulted in the collection of 4 largemouth bass (see Appendix I). Dr. Chris Kelley of HIMB was on site during this event and used cannulation, a catheterization technique, in an attempt to extract eggs from the fish. Dr. Kelley was successful in extracting eggs from 2 of the fish, thereby, confirming they were females. However, eggs appeared to be off-color and irregular in shape indicating they were most likely post-spawn. Dr. Kelley was unable to obtain samples from the other 2 fish, although, visual observation led to his determination that these 2 fish were likely females. All 4 fish were then transported and released into Kualoa Reservoir #3 by the same pre-described methods.

In view of the difficulties experienced in obtaining broodstock, and the realization that many of the fish in Wahiawa Reservoir had already spawned, attempts to collect more fish were terminated and the decision was made to narrow the proposed project. It was then reasoned that

Kualoa Reservoir #3 had sufficient numbers of broodstock to continue the project at this location. An unknown quality and quantity of broodstock, leftover from the initial stocking program in the 1950's, already existed in Nuuanu #3 Reservoir and the decision was made to proceed with the project at this location utilizing the pre-existing stock. There were no pre-existing broodstock at the UH quarry pond and plans to use this location were abandoned.

In the initial stages of this project, trays were visually inspected for eggs each week using standard snorkel gear. However, as this activity disturbed bottom sediments and caused poor visibility, it became necessary to experiment with other methods. A view-pipe, made from a 6 foot section of PVC pipe, open on one end and sealed at the other by plexiglass, was constructed and used to check trays from shore. This method worked well during times of adequate visibility. However, waters were often very turbid making it necessary to rely on sense of touch by feeling the entire perimeter of the trays for the presence of an egg mass. In addition to checking trays, observations were also made by walking around each reservoir and searching for schools of fry. Approximately 3000 mollies were trapped from various small streams and released into Kualoa Reservoir #3 for forage. Due to their self-maintained presence of many years, bass pre-existing in Nuuanu Reservoir #3 were reasoned well fed and no mollies were added to this location. Water chemistry analysis was performed at each location using a "Hach Kit - Fish Farmer's Water Quality Test Kit". Samples were taken during midday from 3 different locations (extreme ends and middle) within each reservoir at a depth of approximately 1ft.

Results and Discussion:

In the third week of March, the largest bass released into Kualoa Reservoir, a 7lb. 8oz. female, was found dead on the surface. This came only 2 weeks after her removal from Wahiawa Reservoir. This fish was badly decomposed and the reason for her death was never determined; however, stress from spawning activity in Wahiawa, being captured, handled, then transported to Kualoa Reservoir were likely factors. Of the 18 bass released into the Kualoa location, this is the only known fatality.

Routine checks of spawning trays at Kualoa and Nuuanu Reservoirs resulted in no findings of eggs. Furthermore, there were no confirmed sightings of fry schools at either location. There was suspicion that a successful spawn did occur at the Kualoa location due to the observation of what appeared to be mollies darting away from bass fingerlings. Further inspection at this location using a throw-net from shore did not confirm the presence of such fingerlings. There were several occasions where coral chips within the trays were found to have been fanned into circular nest-like depressions, such as those commonly formed by nesting largemouth bass. However, Tilapia, which are present in both of these reservoirs, also construct such nests, thereby, making it impossible to determine which species was responsible for the construction.

As the project progressed, it was found to be a common suspicion that bass pre-existing in the Nuuanu location may be stunted (personal communication - Mr. Lance Marugame). Visual observations at Nuuanu supported this suspicion as all bass sighted appeared to be in the same 8 to 10 inch length category. A stunted, or stockpiled as it is often referred to, population could account for the apparent lack of spawning activity at this location as bass this size would most probably be sexually immature. It is not known why these fish would be stunted; however, being that these fish are leftover from the original stocking of Wahiawa Reservoir, it is possible that their genetic make-up is that of slow-growing, smaller-sized fish that enabled them to escape whatever methods were used to capture the larger fish. A second reason that may explain having a stockpiled population is the high level of turbidity that exists at this location. High levels of turbidity result in low penetration of light into the lower depths. This, in turn, results in low production of plankton and aquatic plant life from which invertebrate organisms feed. As growth of the lower trophic levels becomes stressed, growth rates of the largemouth bass are reduced (Bulkley 1975). A final, and perhaps even more plausible, explanation for having a stockpiled population exists as a result of water chemistry analysis performed at this location. Results obtained from analysis on 4/14/97 indicated levels of 5.9, 4.2, and 3.9 mg/L DO_2 (see Appendix II). Each of these levels fall below the 6.0 mg/L level that Bulkley (1975) claims is essential for optimal growth in largemouth bass. With levels this low, not only are largemouth bass stressed, but so too may be the rest of the aquatic community which serves as their food supply. Approximately 5 pounds of live forage are required for each 1 pound weight gain in an individual fish (Lock 1988). Further visual observations at the Nuuanu location did conclude a very limited supply of forage. Whether this limited supply is a product of deficient DO_2 levels, or the result from other predacious species that inhabit the reservoir, was not determined.

Of future concern, in the event that the Nuuanu location may be used again, is that if bass are able to spawn here, Spoor (1977) has shown that their larvae are especially sensitive to DO_2 levels below 4 mg/L. Often times during his study, newly hatched larvae, still containing large yolk sacs, swam vertically towards the surface in an effort to escape the oxygen depleted waters below. This action could result in larvae being lost from the nest by being swept away by currents or taken by predators. Bulkley (1975) also notes that the juveniles ability to swim is greatly impaired at such low DO_2 levels, thereby, making them easy prey for other predators. These findings stress the importance of removing eggs before hatching, as low DO_2 levels at this location may result in survival rates even less than what is commonly found in a natural environment. Additional results of water chemistry analysis at this location, as well as Kualoa, showed no significant findings.

A persistent problem during this project was caused by the high levels of silt that are present in the two reservoirs. This was especially evident at the Nuuanu location where soft-bottom layers in excess of 3 feet have accumulated. Often times, spawning trays at both locations were found smothered by silt deposition. As Eipper (1975) points out, accumulations such as this may totally smother eggs that are not closely guarded by the male and lead to the death of the nest. As the prospect of this happening became apparent, an experimental prototype spawning tray was constructed in an effort to reduce such deposits. This prototype consisted of an original tray housed in a wooden frame constructed with pressure-treated 1 x 4 lumber, and having legs tall enough to keep the tray approximately 8 inches above the silt layer. This tray was placed into the Kualoa location, in close proximity to an existing tray. In the weeks that followed, both trays were routinely checked for silt deposition. While the original tray continued to silt up as before, the new design was effective at reducing silt to a negligible amount. In continuing this program, it would, therefore, be recommended that all trays be constructed in a manner consistent with this prototype.

A similar tray design, described by Inslee (1975), should also be given special consideration. In his design, a window screen lines the bottom of a square frame constructed with 1 X 4 lumber. A smaller basket, fashioned from hardware cloth, is filled with rocks and placed in the center of the frame directly on the screen bottom. This allows the person checking trays to lift the smaller basket from the frame and easily see if any eggs are present. This lifting of the basket lightens the frame which then rises to the surface, keeping trapped within it any larvae that have fallen from the basket. A design such as this, though more costly and time consuming to build, would eliminate all problems associated with visually checking trays in turbid waters.

It is not known what problems, if any, the other species in these two reservoirs presented to the project. Apple snails were a common find in trays at the Kualoa location. Although no literature was found which specifically indicts this species as a consumer of largemouth bass eggs, other species of snails, such as *Viviparus georgianus,* are known to prey upon the eggs. As this happens, the male bass is seemingly unaware of the slow moving predator and takes no action to defend the nest (Heidinger 1975 - quotes Eckblad and Shealy. Reference not available). This suggests that more research is needed before drawing any conclusions about the feeding habits of the apple snail. In addition to snails, there are an abundance of turtles at this location which may also pose a threat to the spawning activities of the largemouth. Also present at both locations are tilapia and convict cichlids. Convict Cichlids are known scavengers of eggs (Kelley - personal communication). Tilapia, although commonly believed to be strictly herbivorous, have been found to turn predacious in waters where adequate plant life was not available. In a case study developed by Trade and Environment (URL #3 - 1997), tilapia are described as being extremely carnivorous of eggs and young of various species and have even led to the depletion of the Guapeta, a species indigenous to Costa Rica. These fish are well adapted to surviving in low-oxygen bodies of water and have the ability to reproduce and grow very quickly. In checking for fingerling bass at Kualoa Reservoir, each throw of the net resulted in the capture of several tilapia of various size. This serves as direct evidence to the success of this species and may be a primary reason for the apparent lack of a successful largemouth spawn.

As for those bass that were stocked into the Kualoa location from Wahiawa, it may be possible that these fish were captured too late into the season to ensure a successful spawn. The stress they experienced from capture, along with the shock of being released into a new location with different environmental conditions from what they were use to, may have caused the females to resorb their eggs. It could also be that these fish had already spawned in Wahiawa, as evidenced in the last few fish captured by the extraction of post spawn eggs. To avoid this problem in future efforts, collections should begin very early in the season, thereby, giving stock sufficient time to acclimate to the new location.

Also pertaining to the stock, it cannot be known with any great degree of certainty that these fish were indeed sexed correctly. Identifying the sex of a largemouth bass by visual field methods may be very misleading. In an effort to determine the accuracy of such tests, Manns Jr. and Whiteside (1979) performed autopsies on 17 largemouth bass that they themselves had sexed by observing the shape of the scaleless area surrounding the urogenital opening. Results of their study concluded only a 59% accurracy. Benz and Jacobs (1986) had similar results of 53% accuracy using this method. When using the genital papilla method, Benz and Jacob reported an 89% success rate in the spring and a 48% success rate in the fall. Their best single method of success came from probing the urogenital opening for probe depth (90% accuracy) and probe angle (94% accuracy). Their highest rate of success (98%) came from a combination of the papilla and probing methods during spring. In future stock collections for this program, this combination may prove to be an efficient means to accurately determine the sex of those bass which do not exhibit obvious gender characteristics. It may also be of great benefit to separate the sexes until such a time that conditions are prime for spawning activity. This action, Lock (1988) maintains, results in a more uniform spawn, thereby, reducing the span in which spawning occurs.

On two separate occasions, spawning trays were found to be removed from the water at the Nuuanu location. While it does not appear that a spawn did occur at this location, it cannot be known for sure that these actions were not responsible for destruction of an actual nest. On the first occasion, the tray was missing and was later discovered to have been thrown into the cover adjacent to the reservoir. On the second occasion, the tray was found pulled onto the bank and fishing line was tangled in the wire structure. It may be possible that bass were sighted on these trays, then fished for by local fishermen. Although this location is closed to public use, there were usually people found loitering in the vicinity during our routine visits.

Conclusion:

Unfortunately, there were no bass fingerlings reared as a result of this project. There were, however, problems resolved and information gathered that will go towards insuring the future success of this program. There are still problems that need attention; however, since DLNR has allocated funding for the continuation of the stock enhancement program, these problems will undoubtedly be resolved as well. This program is being performed with the cooperation of DLNR, HIMB, and local fishing clubs HFFA and AFSA. This unique combination adds strength to the program as each of these groups will benefit by its success and are genuinely interested in improving the situation at Wahiawa Reservoir. As for myself, becoming involved in this project has greatly enhanced my knowledge of the largemouth bass species and will certainly add to my preparation for a career in fisheries management.

Acknowledgments:

This project could not have been performed without the efforts of Dr. Chris Kelley of HIMB. Dr. Kelley was very patient in working around my own hectic schedule and readily made himself available upon request. He provided a wealth of information, not only towards this project, but also in other areas of fisheries management that has greatly inspired me to learn more about this field. Also critical to the success of this project has been the efforts produced by members of HFFA and AFSA. It is their persistence to improve conditions at Wahiawa Reservoir that has inspired this program and this project. Not only do these members make valuable suggestions regarding the program, they become actively involved in running it. In addition to capturing the stock for the program, HFFA members were also instrumental in obtaining mollies for Kualoa Reservoir. Deserving special mention is Lance Marugame of HFFA who has been a constant source of reference for this project and a leader in the effort to improve conditions on Wahiawa Reservoir. Glenn Higashi of DLNR also provided time and effort in collection and transport of bass from Wahiawa. An integral part of the program, Bo Alexander of HIMB, was available to help on numerous duties involved in this project. Thanks also to Mr. Farouk Wang and his crew at UH. Although the quarry pond at UH was never used, Mr. Wang and his crew gave their careful consideration and approval for its use and were eager to see its success. Special appreciation goes to Sherwood Maynard and Steve Russell of MOP for their encouragement and guidance on this project.

Largemouth Bass
Taken From Wahiawa Reservoir

Taken on 2/2/97 by HFFA/AFSA

#	Sex	Length (in.)
1	F	16
2	F	17
3	F	17
4	F	17
5	F	17.5
6	F	18
7	F	18.5
8	F	18.5
9	M	16
10	M	16
11	M	16

Donated by Lance Marugame on 2/9/97

#	Sex	Length (in.)
1	M	13.5
2	M	13
3	M	12.5

Taken on 3/2/97 by HFFA

#	Sex	Length (cm.)	
1	F	44	
2	F	59	(7lb 8oz)
3	F	29.5	
4	F	43	

Water Chemistry Results

From 4/14/97

	Kualoa #3 Reservoir			Nuuanu #3 Reservoir		
	near end	middle	far end	near end	middle	far end
Temperature (F°)	84.6	86.0	82.6	77.4	73.4	72.3
DO_2 (mg/L)	8.0	8.7	7.9	5.9	4.2	3.9
Alkalinity (mg/L)	85.5	85.5	85.5	51.3	51.3	51.3
CO_2 (mg/L)	10-15	10-15	10-15	10-15	15-20	15-20
Salinity (mg/L)	100-150	100-150	100-150	50-100	50-100	50-100
Chloride (mg/L)	60-90	60-90	60-90	30-60	30-60	30-60
pH	7.5	6.5	6.5	7.5	7.0	7.0
Hardness (mg/L)	68.4	68.4	68.4	51.3	68.4	68.4
Nitrite-N (mg/L)	0.02	0.015	0.0	0.02	0.037	0.0
Nitrite-NO_2 (mg/L)	.066	.0495	0.0	.066	.1221	0.0
Ammonium-N (mg/L)	.4	.25	.4	.25	.3	.3
Ammonia (mg/L)	>.0149	>.0024	>.0033	>.0071	>.0019	>.0019

Appendix II

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